Urban mass and energy flow analysis by means of cost surfaces

the example of combustible household waste

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Urban mass and energy flow analysis by means of cost surfaces: The example of combustible household waste

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Why bother about waste flows?

- Denmark combusts 1.5 mio t household waste annually
- This equals 37 PJ of the primary energy supply (4.4%)
- Waste comprises 29% of fuel demand for district heating

- Are municipal waste solutions optimal?
- What happens when the number of municipalities is going to be reduced from 271 to 98?
- What happens if future waste incineration is being centralised?

Waste management in Denmark

- Thoroughly regulated
- Coordination in all phases of waste disposal
- Obligatory, holistic municipal waste plans
- Treated in joint-municipal companies

- Non-recyclable waste is incinerated for production of heat and electricity
- Waste is transported up to 150 km to be incinerated
- Waste transport is costly and difficult
- Amounts of waste treated depend on heat market

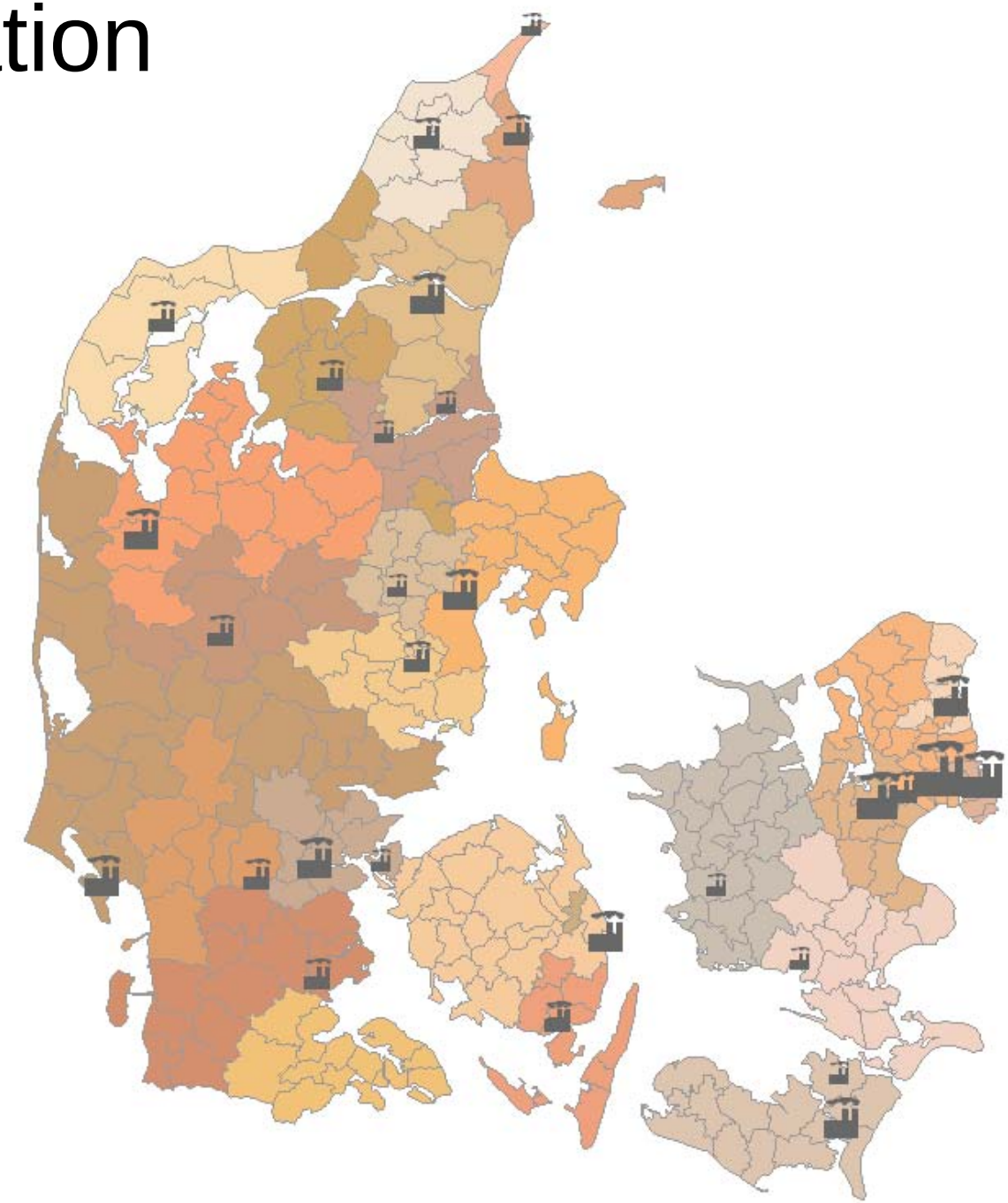
Waste incineration plants

The current layout of waste incineration infrastructure is a product of decades of planning.

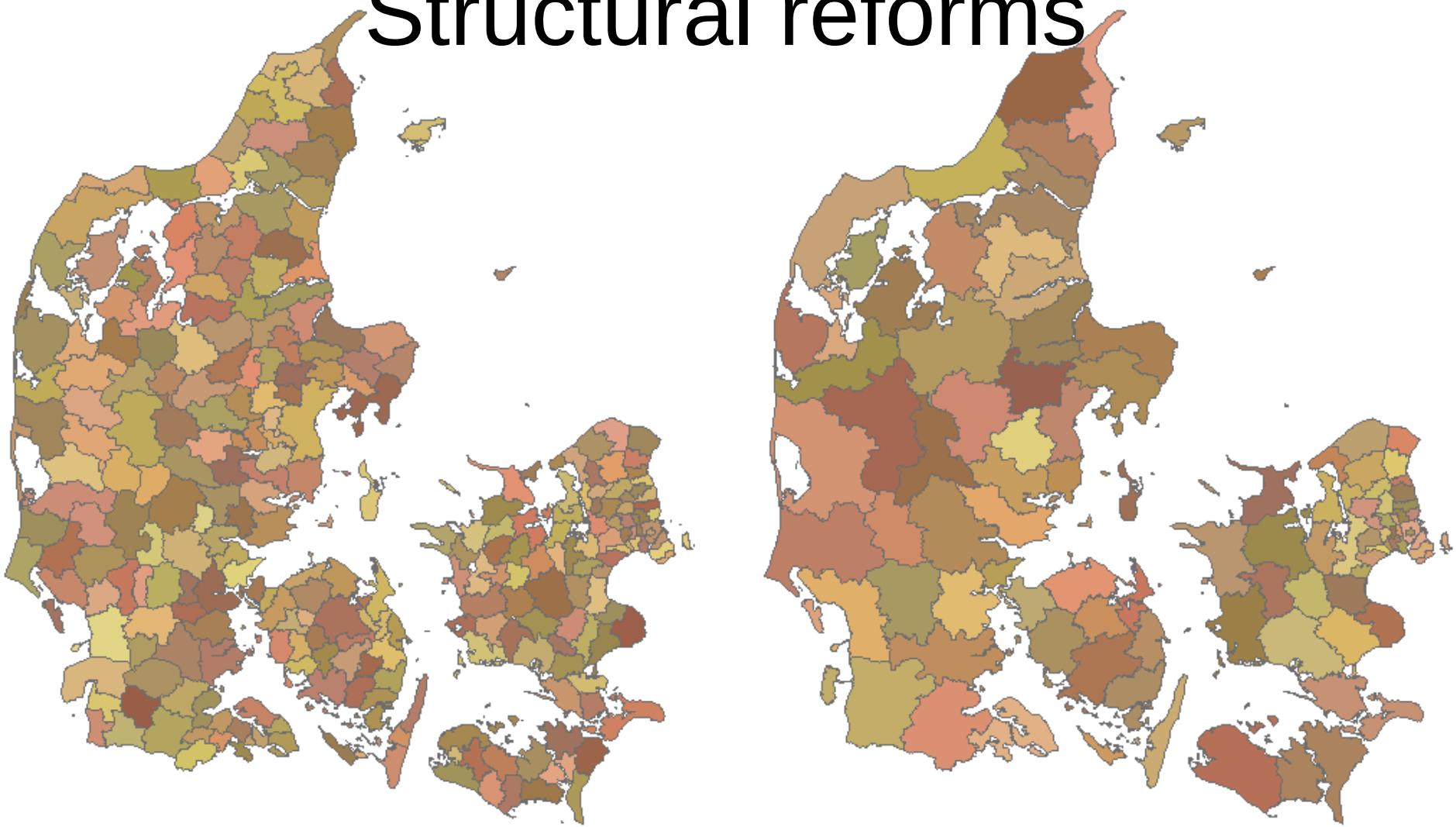
Location is determined by:

- administrative structure
- the district heat market
- minimal incinerator size.

The question is whether plants are located optimally if the spatio-administrative structure changes.

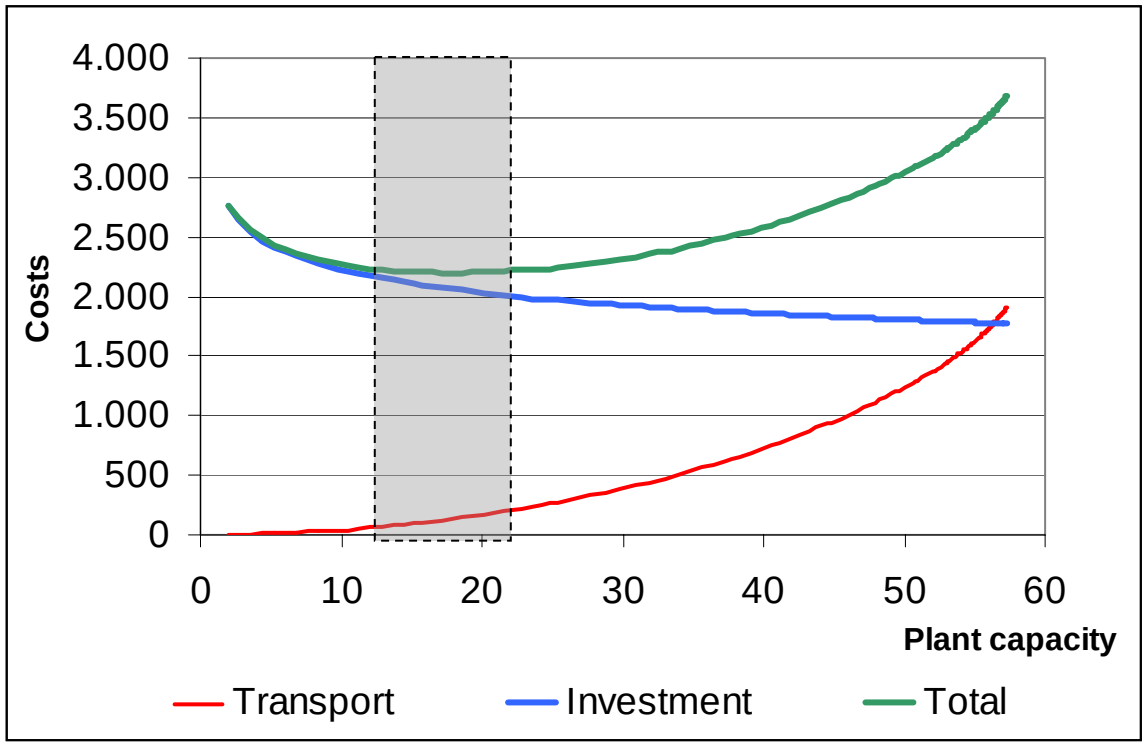


Structural reforms



Merging 271 municipalities to 98 by 2007 will probably affect the spatial order of waste removal. New optimal locations of incinerators will emerge if transport distance and district heat market are optimised.

Location, resources and economy



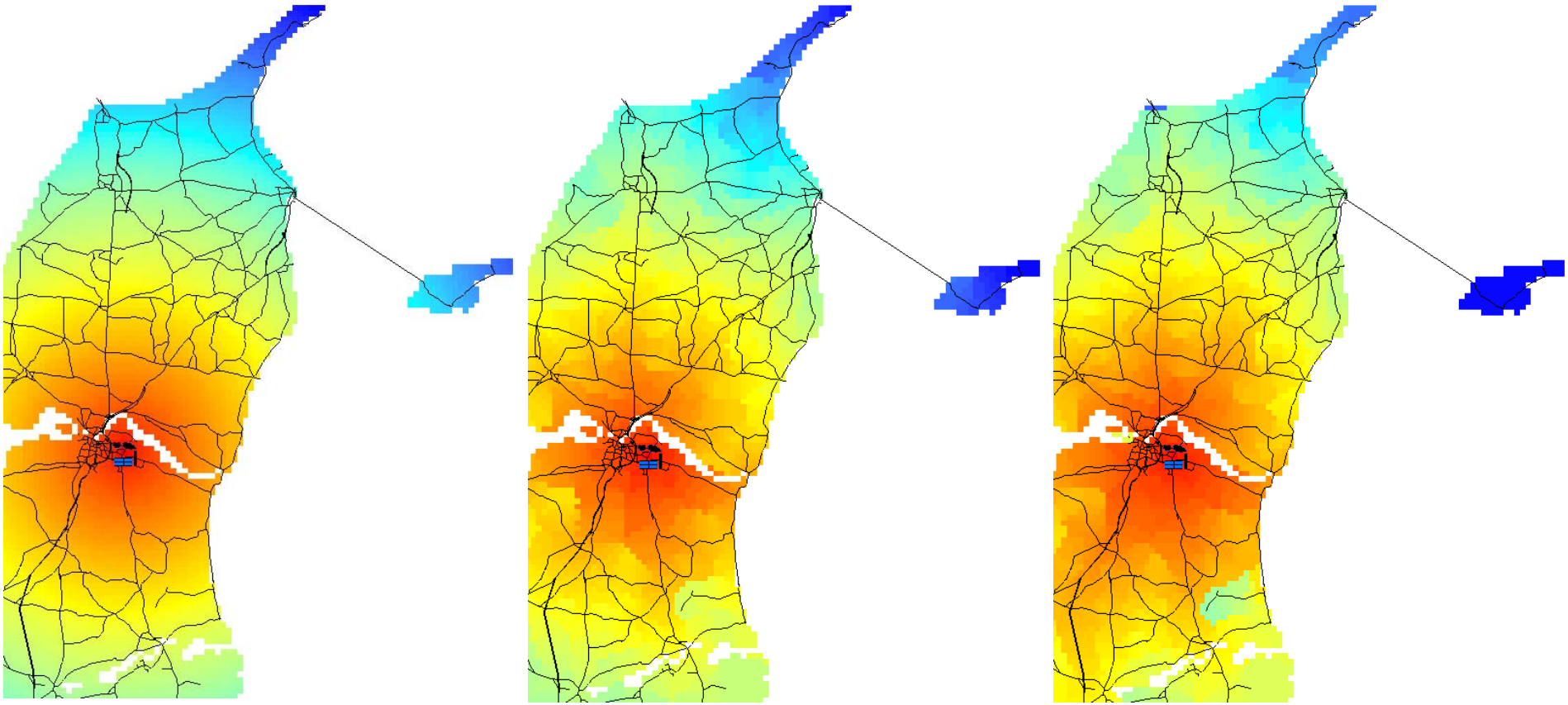
Distribution of waste in a region determines transport costs and plant size

Transport costs increase with distance and the amount allocated to a plant

Investment and operation costs decrease with plant size

For a given location an optimal plant size can be defined

The concept of cost surfaces



Straight line distance

Distance on road network

Travel time on road network

Cost surfaces following road network infrastructure take into account the variation of transport costs. Urban density of waste and routed transport have to be considered.

Waste resource mapping

A 1 km^2 raster with population data (no. of households) was used to spatially distribute amounts of combustible household waste

Socio-demographic parameters such as age, income, household size were not included as yet

Waste is quantified in tonnes / km^2

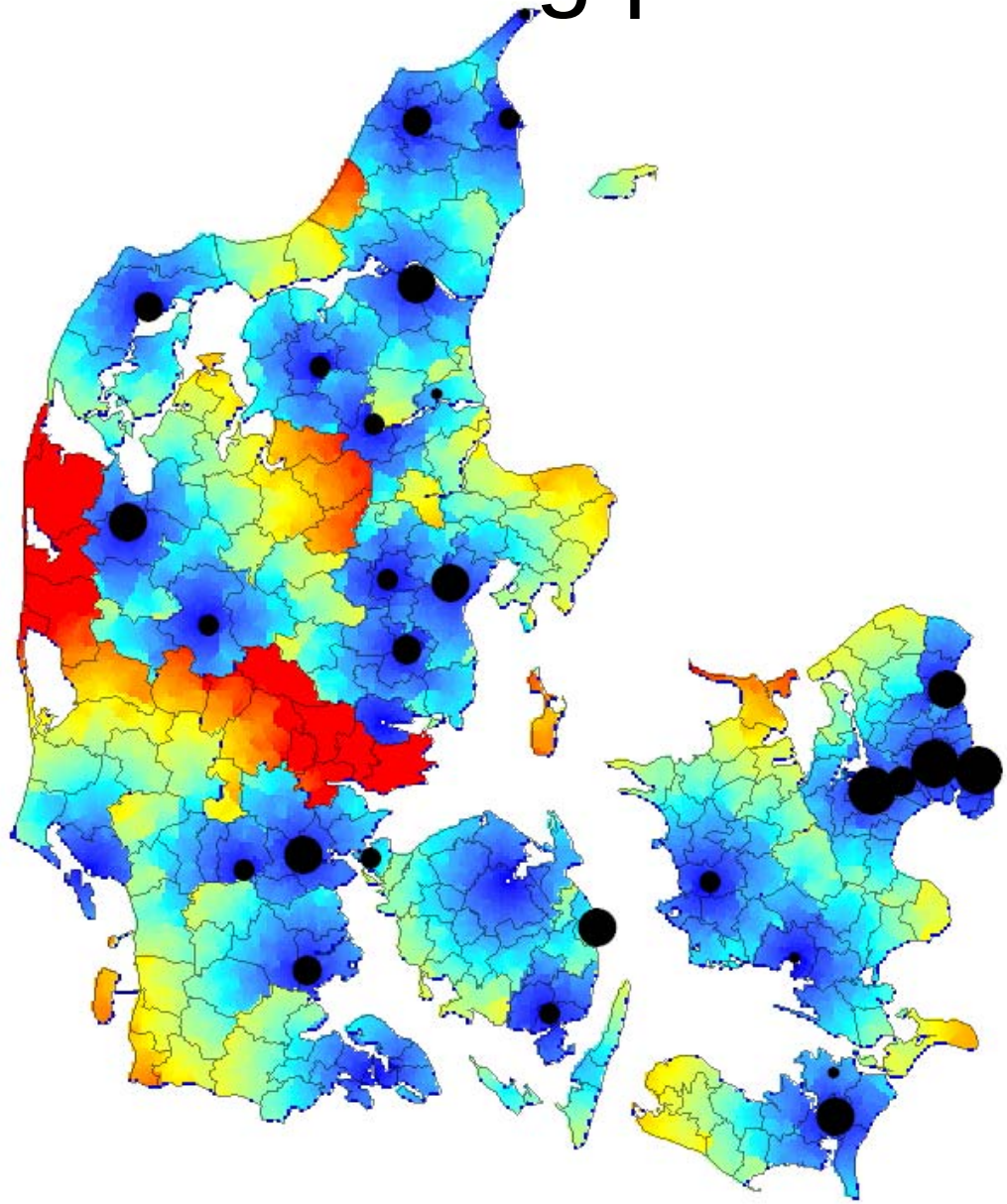
The waste resource map is used for the site-specific analysis of removal costs by distance and amounts

Results: transport to existing plants

Transport distances from within the boundaries of each waste treatment company are mapped as cost surfaces via the road network.

This map reveals considerable differences in the transport distances to incineration plants.

These differences can motivate the re-organisation of the spatial structure of waste management.

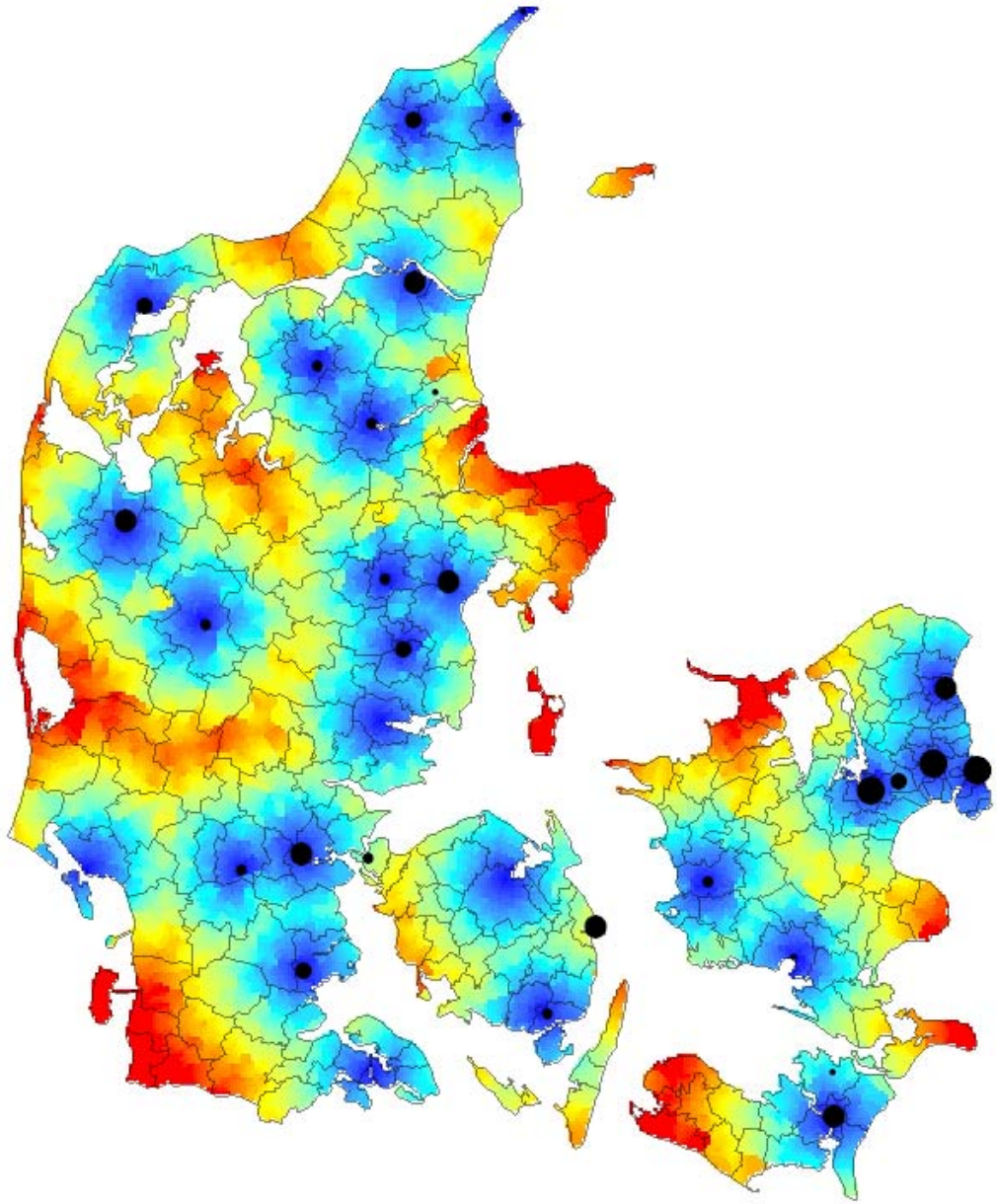


Results: natural basins

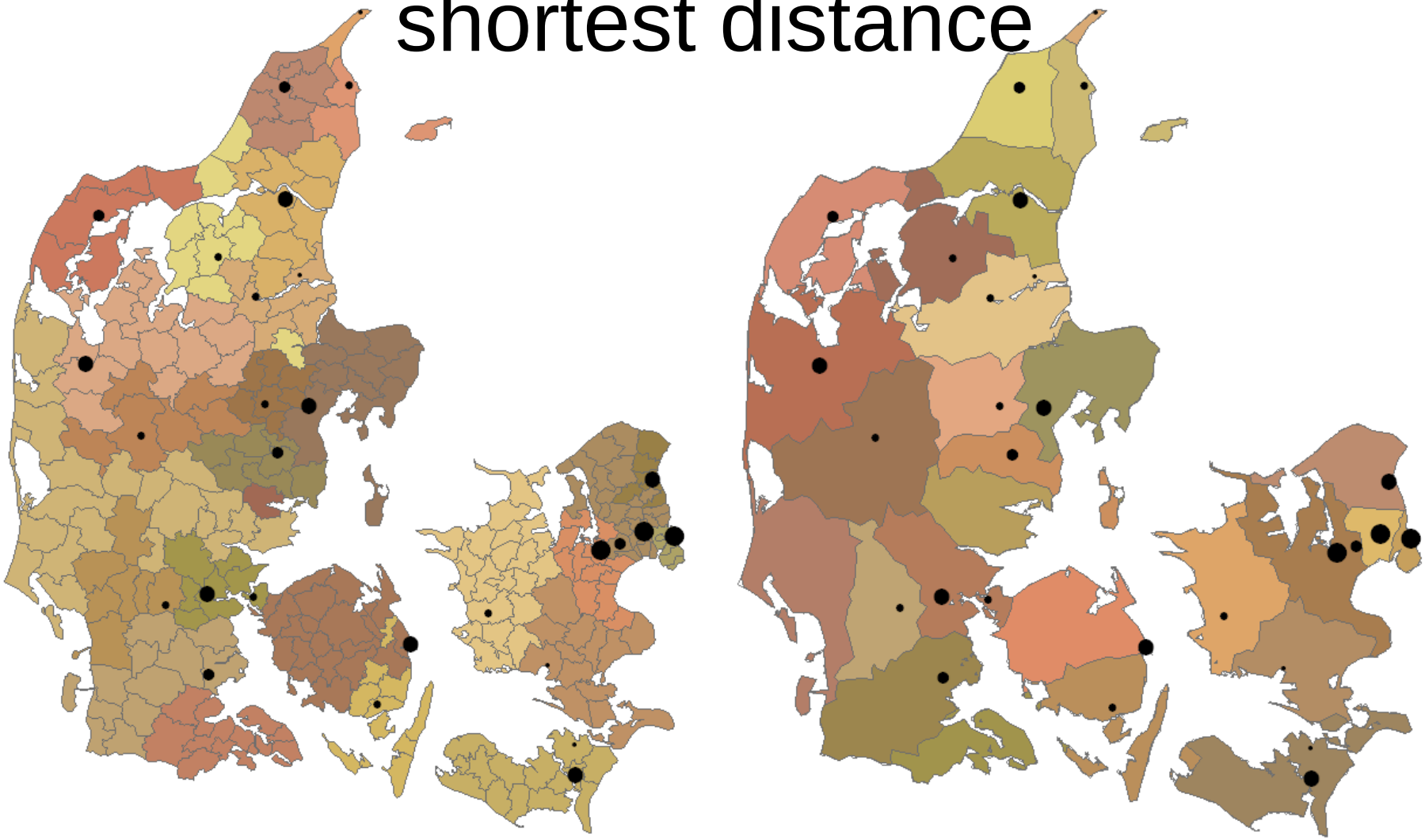
By letting the distance to the nearest incineration plant be decisive for the allocation of waste to incineration plants, overall transport work (tonne-km) is minimised

This can be used to propose new waste removal contracts, given that incineration plants have a heat market large enough

Heat markets are often limited by the size of district heating networks



Results: removal zones based on shortest distance



New zones based on shortest distance (right) reduce the need for waste transport from 38 to 29 mio tonne km (minus 24%) compared to the existing zones (left).

Conclusions

- Waste incineration seems to be suboptimal in terms of transport requirements
- Transport volumes could be reduced if waste was collected from natural basins
- Natural basins however do not match urban heat markets
- To be included in further studies:
  - Socio-demographic mapping of waste amounts
  - Empirical data on collection costs in urban/rural areas
  - Allocation of waste to plants by least costs
  - Integration of all costs into a holistic planning model

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